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# **Reliability-Based Maintenance as a Breakthrough Strategy in Maintenance Improvement**

by  
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## **Introduction**

Industrial plant maintenance is gaining attention as the next great opportunity for manufacturing productivity improvement. As companies invest in more high-tech and expensive equipment, they become more reliant on the need to reduce equipment redundancy without sacrificing reliability and availability, accomplishing this within an ever decreasing availability of operating capital. E I Dupont has said that maintenance was once its "single largest controllable cost opportunity, representing \$100-\$300 million per year corporate wide". It is estimated that U.S. Industry needlessly squanders in excess of \$200 billion each year on inadequate or unnecessary maintenance procedures. Within the last ten years a wide range of advanced maintenance technologies have been developed which can help manufacturers reduce their maintenance costs while simultaneously increasing plant reliability.

Reliability-Based Maintenance (RBM) has emerged as perhaps the preferred advanced maintenance philosophy in North America. RBM was initially conceived as a solution advocating the logical balance between the four technical strategies of traditional maintenance: reactive, preventive, predictive, and proactive maintenance. Since the Reliability-Based Maintenance "recipe" has evolved to additionally include the appropriate technical strengths of Reliability Centered Maintenance (the RCM Process) and the people/work concept of Japanese-based Total Productive Maintenance (TPM). This broadened formula for Reliability-Based Maintenance has been driven by users and implementers in an effort to incorporate the tangible benefits of all advanced maintenance strategies and philosophies into a single deliverable solution. A historical perspective of the development of the various maintenance strategies follows.

## **Historical Discussion of Maintenance**

In surveying the last sixty years there has been an enormous evolution in the sophistication of machinery used in production processes, mainly driven by the demand for increasing productivity as a competitive issue. This has led the equipment evolution from purely mechanical systems to precision electro mechanical systems with sophisticated computerized controls.

Pre-1930 machinery was robust, overdesigned, and long lasting. The major failure modes were wear or metallurgical. The maintenance plan was simple, machinery was rebuilt after failure by skilled craftsmen. In the 1950's productivity was becoming more of an issue. The prevailing maintenance philosophy was the belief that "machinery failure" was an accepted and unavoidable part of manufacturing life. This led to designing processes which had significant standby capacity and large spares inventory, with a strategy of ever increasing scheduled intervention (addictive maintenance). It was also a time of evolving relations between the workforce and management where Unions played a defining role, creating strict job definitions within the maintenance organization.

Until the early 1970's, most plants worldwide performed maintenance in a reactive, or breakdown, mode. Reactive maintenance is expensive because of extensive unplanned downtime and damage to machinery. With the availability of mainframe computers in the 70's, many companies implemented periodic preventive maintenance strategies to encourage planned maintenance inspection and repair in preference to reactive maintenance. This still dominant maintenance approach typically utilizes maintenance scheduling software to track and schedule calendar-based maintenance activities, and to automatically trigger required work orders. As the adoption of preventive maintenance grew, original equipment manufacturers habitually began to oversubscribe PM recommendations in an attempt to reduce their warranty exposure, thereby increasing overall maintenance costs with needless open-and-inspects.

As maintenance costs ballooned, a maintenance optimization procedure called Reliability-Centered Maintenance (RCM) was developed in the late 70's to help reduce the ever increasing volumes of work orders resulting from the implementation of computerized scheduling. The early RCM procedures were heavily influenced by safety issues because RCM has its origins in the airline industry. About the same time a maintenance philosophy called Total Productive Maintenance (TPM) was gaining momentum, particularly among Japanese manufacturers. TPM advocates a partnership between maintenance and operations departments such that basic maintenance activities (cleaning and inspections) are performed by operators. TPM has been adopted successfully in Asia and some parts of Europe, but it has suffered in North America due to union opposition.

In the mid 1980's, advances in instrument technology coupled with widening adoption of the personal computer provided the capability of "predicting" machinery problems by measuring machinery condition, using vibration, thermal, and ultrasonic sensors. This technology is commonly referred to as Predictive Maintenance (PDM), or condition monitoring. Another more advanced maintenance strategy called Proactive Maintenance (PAM) assists in further extending the failure cycles of plant machinery through the systematic removal of failure sources. Finally, in 1992, Reliability-Based Maintenance was introduced which effectively combines the strengths of all of the aforementioned strategies and philosophies into a single deliverable maintenance solution.

As we review the history of maintenance it is interesting to observe that prior to the early 1970's, the maintenance function was little changed since the beginning the industrial age. There were no improvement strategies developed, no re-engineering attempts, little investment and attention. The perceived purpose was to, first, repair things when they failed, and second, paint the parking lot and mow the grounds for visitors. Until recently, maintenance has always been perceived as a "necessary evil", beyond optimization and improvement.

Today, machinery is a complex hybrid of semiconductor controlled electro mechanical devices designed to operate with a much more demanding duty cycle. The maintenance manager in every manufacturing environment must now ask himself where he and his team stand in terms of whether they are sufficiently equipped, trained and organized to be effective and competitive. Modern maintenance has to be in step with the demands of a much more sophisticated manufac-

turing environment. In order to succeed the basic philosophy of maintenance must continue to evolve in step with the changing demands of manufacturing and competition. An owner, in order to be competitive, requires maximum uptime from the machine operating at near its design capacity. And of increasing concern is the environmental aspects of the effect of plant operation.

Progressive companies are perceiving that maintenance is a worthy investment area, and as such the investment has to be carefully managed and measured for its returns. From this, the ideas and practices of our breakthrough process have evolved. One difficulty has been the establishment of well accepted metrics of maintenance performance in order to apply tangible criteria against alternative competing investments.

### **Financial Impacts of Maintenance**

Let us explore some of the more significant issues which the maintenance function impacts on a day-to-day basis. First, and most obvious, is production availability. Without 100% process and machinery uptime, we have less than 100% production availability, resulting in lower than planned sales. But can't lost production be made up on weekends? It certainly can if eroding margins are acceptable. Of course, one might consider shipping out of built up inventory so long as this doesn't conflict with company Just-In-Time manufacturing plans.

A second impact of maintenance is product quality. It stands to reason that well-balanced and well-aligned machinery and processes will produce a consistent, higher-quality product. But can't off-quality product be re-worked? It certainly can if eroding margins are of no concern. Of course, one might consider shipping the off-quality product anyway, so long as Quality isn't an issue with the company's customers.

Insurance premiums are another consideration. Many manufacturing facilities purchase "downtime insurance" in case of catastrophic failure. Some major insurance companies provide advanced high-tech maintenance services, the cost of which if utilized by the customer, is offset with low insurance premiums. NRC regulations require "efforts to predict and prevent machinery failure" in broad terms, punishable by hefty fines. Energy consumption is still another consideration. Manufacturing facilities typically waste significant excess energy in operating poorly aligned and lubricated power transmission systems. How about safety and loss-time injury? Over 50% of loss-time injury accidents occur within maintenance, the majority of which result from the panic pressures of getting equipment back on-line after failure.

An important additional requirement for consideration today is minimal environmental impact from associated production processes. Within this new assignment, maintenance has enormous responsibilities. The consequences for failure cannot only be safety critical but can have enormous negative reputation implications for the corporation. One only has to recall Union Carbide's Bhopal, India disaster as a reminder.

The significant point made is that the implications of an advanced maintenance strategy (or the lack of one) are far-reaching within the corporation. The measured budget line item costs of maintenance typically range between 5-and 15% of total costs depending upon the process, but at what place in the company's income statement are the implications of reactive-type mainte-

nance on production availability, injury avoidance, power consumption, environmental regulations, and insurance premiums represented? Typically not in maintenance. As we begin to recognize the far reaching economic and fiscal impacts of maintenance, we must also recognize that we will need to define new ways to measure maintenance performance.

### **A Business Perspective of Maintenance**

Businesslike demands are often made of the maintenance function, but seldom is the performance of maintenance measured from a business viewpoint. Most operations managers suggest that the maintenance function should be measured by the **uptime** parameter. Maintenance technicians, however, voice that they have little real control over uptime, and that "downtime" is more a result of excessive machinery abuse related to production demands rather than improper maintenance procedures. In fact, maintenance is more commonly measured by the "speed in which machines are back-up-and-running after catastrophic failure".

Another popular measure of maintenance performance is labor overtime. Logic should tell us that labor overtime is not a valid measure of performance. It is more a measure of nonperformance. Put simply, if we demand reduced overtime, we are not seeking improved performance, but instead are simply seeking a reduction in nonperformance.

Maintenance as it is typically measured is a "zero-sum-gain", and in a zero-sum world, all one can do is hope to break-even. Even if maintenance aggressively manages their expenses and comes in under budget, the question has to be asked "What was sacrificed?"..... Availability,...Quality,...Capacity? To reiterate, if these parameters are not measured in relation with each other, how can one truly quantify positive gains in a zero sum world ?

World-class manufacturers monitor their performance by the parametric measures of quality (ergo Deming's influence), cost ("value" is the politically correct term), and delivery (just-in-time). Maintenance should be measured similarly. Maintenance manufactures capacity, so world-class maintenance organizations should be measured against their capacity quality, capacity costs, and capacity delivery.

No company can be a world class competitor if it's factories are not up to the task. It is therefore an issue of the highest strategic importance to create a maintenance function which provides maximum capacity and availability at optimum costs. The concepts of Reliability Based Maintenance provide a framework to achieve "**Breakthrough**" within the maintenance function, measured by a set of metrics consistent with other critical business performance measures within the organization. This marks the beginning of the recognition that maintenance provides a significant opportunity for manufacturing productivity improvement.

### **Reliability-Based Maintenance**

An effective Reliability-Based Maintenance operation is not just a well run refined predictive maintenance effort, but a new philosophy which forces fundamental shifts in the way maintenance is managed and measured. A first step towards breakthrough is to understand the function of maintenance. The function of maintenance in a world-class operating environment is

not to simply maintain, but to provide reliable production capacity and to extend the life of plant assets at optimum cost. The consequences of unreliable capacity are interrupted production schedules, lesser quality, and, most importantly, diminished profits. With reliable production capacity in mind, the most progressive manufacturers are restructuring their maintenance departments from specializing in reacting to breakdowns to organizing for the systematic elimination of machine failure, thereby increasing availability while minimizing maintenance costs.

Reliability-Based Maintenance is an advanced maintenance philosophy which prioritizes plant systems in terms of their impacts on capacity and availability, and forces the appropriate balance of reactive, preventive, predictive, and proactive maintenance strategies to insure maximum capacity and availability while minimizing costs. The seven primary breakthrough concepts advocated by Reliability-Based Maintenance include:

- (1) Prioritization of plant systems and failure modes in terms of their impact on capacity and availability,
- (2) A business decision of where to invest maintenance resources,
- (3) An infusion of available maintenance technologies including preventive, predictive, and proactive technologies,
- (4) An increase in the core competency of the maintenance function,
- (5) A redefinition of the maintenance function whose mission is to pursue productivity and capacity improvement solutions, through "Breakthrough" practices,
- (6) An increased awareness throughout the plant of the implications of maintenance decisions, and,
- (7) An establishment and acceptance of suitable business performance metrics for maintenance.

Predictive Maintenance technologies combined with a state-of-the-art computerized maintenance management system are the catalyst of change in enabling a breakthrough change in maintenance practices. The implementation of Reliability-Based Maintenance requires a balance of reactive, preventive, predictive and proactive maintenance strategies. These reliability improvement strategies are not independent; they frequently draw upon each other's strengths in achieving reliable plant capacity.

### **Restructuring of the Plant Reliability Department**

The adoption of RBM concepts over traditional maintenance concepts requires a significant redefinition of employee roles and responsibilities, combined with a restructuring of accountability with and between other plant departments.

First, RBM encourages a slow, but deliberate, migration to the work methods promoted by Total Productive Maintenance. This encourages the elimination of traditional organization lines between production and maintenance, lines which many times prevent operators and mechanics from taking immediate action to correct a simple problem. Operators should begin to assume responsibility for the performance of basic house-keeping activities including cleaning, routine inspection, and certain other tasks suggested by maintenance. This strategy further employs a

team approach to continuous improvement wherein production and maintenance systematically maintain and improve equipment effectiveness.

The five "pillars" of TPM as described by its founding father, Seiichi Nakajima, include:

1. Maximizing Equipment Effectiveness
2. Involving Operators in Daily Maintenance
3. Improving Maintenance Efficiency
4. Training to Improve Skill Levels
5. Emphasis on Maintenance Prevention.

A look at how RBM enhances these five pillars follows.

#### *Maximizing Equipment Effectiveness*

Improved equipment effectiveness can be achieved through "elimination of the five big losses", the largest contributor being **machine failure**. RBM strategies include predictive technologies which not only predict machine failure, but also proactive techniques which eliminate machine failure and extend life cycles. Additionally, RBM promotes extending machine operating conditions beyond design levels.

#### *Involving Operators in Maintenance*

One of the most valuable "predictive" indicators is derived from visual observations. Operations personnel are the closest to equipment, and the persons most likely to be aware of changes in machine or process condition. The RBM strategy emphasizes a close working relationship between maintenance and operations. Operator feedback to the RBM department provides vital information for the root-cause-failure-analysis cycle.

#### *Improving Maintenance Efficiency*

The RBM philosophy is based on the use of advanced maintenance technologies to eliminate unneeded preventive activities, and to refine the PM cycle. Predictive technologies dramatically improve efficiency. Additionally, RBM philosophies promote the concept of benchmarking and continuous improvement planning.

#### *Training to Improve Skill Levels*

RBM philosophies stress the elevation of skill levels. RBM forces an understanding of preventive strategies, predictive technologies, and proactive work methods. Additionally, predictive technologies often uncover the need for training in other areas such as downtime and change-out practices.

#### *Emphasis on Maintenance Prevention*

A strong benefit of RBM is that it forces the accumulation of machinery information and equipment histories. Chronic problems are identified and eliminated. Design deficiencies are identified, and the resulting information is used in future purchases of equipment. Proactive practices embody many maintenance prevention activities including improved purchase specifica-

tions, installation commissioning, and precision alignment, balancing, and lubrication methods.

TPM work methods are essential to Reliability-Based Maintenance. As operations assumes more and more housekeeping activities, valuable free time is created for the maintenance function so as to persurve reliability improvement activities. RBM promotes the development of a more highly-skilled, flexible workforce, and in doing so, optimizes the size and cost of the workforce.

### **Implementing Reliability-Based Maintenance**

#### **PHASE ONE - DISCOVERY**

During the initial phase of discovery, the maintenance function must perform some formulating activities allowing assessment of current practices, performance measures, objective, and prevailing attitudes. Many have assumed that they can skip this phase and move directly to stabilization, but success rates drop dramatically. The significant point is that one cannot develop a plan of where to go without the knowledge of where one is. There are perhaps two dozen major indices which need to be analyzed during the discovery phase, the results of which produce a viable and workable continuous improvement plan for the difficult period ahead.

#### ***Philosophical Elements***

- ◆ Organization Structure
- ◆ Prevailing Attitudes
- ◆ Work Methods
- ◆ Quality Measures
- ◆ Mission Effectiveness
- ◆ Performance Objectives and Measures

#### ***Procedural Elements***

- ◆ Work Control Procedures
- ◆ Document Control Procedures
- ◆ Maintenance Prevention Procedures
- ◆ Training Plans
- ◆ Major Projects Procedures
- ◆ Spares Control Procedures

#### ***Technical Elements***

- ◆ CMMS Program
- ◆ Predictive Technologies Program
- ◆ Proactive Maintenance Program
- ◆ Reactive Maintenance Program
- ◆ Preventive Maintenance Program
- ◆ Technical Training
- ◆ Balance of Maintenance Strategies

A new mission is defined for maintenance with bottom-up and top-down buy-in; coupled with a new set of business-based performance measures.

## **PHASE TWO - STABILIZATION**

The first step of stabilization is to create two key dedicated core functions; 1) Maintenance Planning Group, and 2) Reliability Improvement Group.

These two groups are the hubs for the Reliability-Based Maintenance strategy. The Maintenance Planning Group may exist as a preventive maintenance group already; however its focus needs to be changed from work order generation and tracking to full scope maintenance planning.

### ***Responsibilities of Preventive Planning Group***

- ◆ Coordination of all preventive maintenance,
- ◆ Coordination of minor housekeeping activities performed by operators.
- ◆ Coordination of maintenance activities with production to obtain the least impact on availability.
- ◆ Maintenance work planning, including procedures, tools, parts, inspections, and calibration.
- ◆ Work order tracking and cost tracking.
- ◆ Machine history file.
- ◆ Evaluation of life cycle trends for possible machinery improvement needs.
- ◆ Spare parts management.

The Reliability Improvement Group is initially focused on the implementation of predictive technologies in the plant, but also moves toward proactive strategies as the group matures. This group is usually made up of experienced machinery mechanics or technicians, chosen for their machinery maintenance ability as well as their capacity to learn new, advanced maintenance techniques. The typical Reliability Improvement Group at a large plant starts with one or two vibration technicians, one thermography technician, one lubricant engineer and one maintenance engineer. The group should be chosen from existing plant staff and trained to become experts in their area of specialty. At this stage the importance of training cannot be overemphasized.

### ***The Responsibilities of the Reliability Improvement Group***

- ◆ Operating a self-directed predictive maintenance team integrating all predictive maintenance technologies.
- ◆ Providing timely component condition evaluations to Maintenance Planning, with the goal of eliminating all unplanned downtime.
- ◆ Performing ongoing SERP analysis.
- ◆ Implementing proactive maintenance technologies and methods, including identification of recurring problems.
- ◆ Tracking performance measures e.g. savings from single event analysis, uptime/downtime, maintenance costs, quality, etc.
- ◆ Identification and elimination of unnecessary preventive maintenance activities.
- ◆ Identification of equipment design changes to improve reliability.
- ◆ Management of the plant's computerized maintenance management system.

More predictive maintenance technologies are added during the second and third year of stabilization. During this stage, machinery condition information is thoroughly integrated with preventive maintenance and proactive technologies, including precision alignment, balancing, and root cause failure analysis. The Reliability Improvement Group will grow to several dozen

people for a large industrial facility, while the preventive planning group may shrink by 30% or more. Also during this stage, the plant attitude toward maintenance begins to change. Management promotes the elimination of breakdowns and employee attitudes change significantly toward predicting and eliminating problem sources.

The performance measurement of the Reliability Improvements Group begins to shift from single event analysis to global improvement indicators.

### **PHASE THREE - BREAKTHROUGH**

This stage is most noteworthy for the attitude change which has occurred within the maintenance department.

Benchmark plants stand out strongly against industrial norms in terms of management and employee emphasis on Reliability-Based Maintenance philosophies. In this stage of aggressive implementation of the strategy, the plant is entirely focused on eliminating breakdowns, permanently eliminating machinery and quality problems, and achieving nameplate (theoretical) productivity or better. The performance measurements for the success of the strategy focuses on shift bottom line measurements consistent with the plant's business - maximizing operating and maintenance costs, and striving for greater profitability and working capital.

Procedures for all aspects of the maintenance business are developed and documented including: document control procedures; major project procedures; and a dynamic flexible master work control procedure.

The work methods within the plant have evolved to a point of full partnership between maintenance and operations in terms of maximizing reliability and controlling costs. The Reliability Group is now the Reliability-Based Maintenance Department operating with full responsibility